

Accelerated Test Method for Corrosion Protective Coatings

Completed Technology Project (2014 - 2015)



Project Introduction

This project seeks to develop a new accelerated corrosion test method that predicts the long-term corrosion protection performance of spaceport structure coatings as accurately and reliably as current long-term atmospheric exposure tests. This new accelerated test method will shorten the time needed to evaluate the corrosion protection performance of coatings for NASA's critical ground support structures. Lifetime prediction for spaceport structure coatings has a 5-year qualification cycle using atmospheric exposure. Current accelerated corrosion tests often provide false positives and negatives for coating performance, do not correlate to atmospheric corrosion exposure results, and do not correlate with atmospheric exposure timescales for lifetime prediction.

Evaluation of metals and corrosion protective coatings to predict service life of metal-based structures in corrosive environments has long relied on atmospheric exposure testing. Traditional accelerated corrosion testing relies on mimicking select variables of the exposure conditions, often incorporating salt spray and ultraviolet (UV) radiation, and exposing the metal to continuous or cyclic conditions, similar to those of the corrosive environment. Their reliability to correlate to atmospheric exposure test results is often a concern when determining the timescale to which the accelerated tests can be related. Accelerated corrosion testing is not a universally accepted tool in predicting the long-term service life of a metal, despite its ability to rapidly induce corrosion. A major complication with accelerated corrosion methods is that the resulting corrosion products do not mimic corrosion products that occur naturally during atmospheric exposure. Therefore, while the corrosion is accelerated, as indicated by a higher corrosion rate, the corrosion environments are not relatable. It is widely agreed among corrosion control experts that a method that correlates timescales from accelerated testing to atmospheric exposure would be very valuable. This project involves gathering all the background literature in the field of accelerated corrosion testing, previous results from the characterization of the atmospheric environment at the Kennedy Space Center (KSC) Beachside Corrosion Test Site, and a review of previous work involving its correlation to accelerated corrosion methods in which accelerated corrosion conditions were compared to identify possible timescale correlations between accelerated and long-term corrosion. Based on this information, the following technical approach was formulated:

In order to determine the driving factors for each of the different variables causing corrosion product formation, a series of different test apparatuses that isolate or eliminate one or more of the variables was determined. The resulting data from variable manipulation will be compared to long-term atmospheric exposure test data. The test hardware types are discussed in the following sections according to their controlling variables.

UV Light, Temperature, Water Vapor, Chlorides, Precipitation, and Wind



Beachside Atmospheric Exposure Test Site at NASA's Kennedy Space Center

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The natural environment at the atmospheric exposure test site includes all of the variables and corrosion-inducing conditions to which all of the other test data will be compared.

Seawater Mist, UV Light, Temperature, Water Vapor, Chlorides, Precipitation, and Wind

The Alternative Seawater Spray Test (ASST) includes a seawater spray nozzle system that is combined with the natural environment at the atmospheric exposure test site. This test will isolate the driving factor of additional salts and wet and dry cycles.

UV Light

A chamber that emits only UV light in order to isolate the cumulative effects of UV light on the various coatings and metal types chosen in the study. This chamber also controls temperature to maintain constant environmental conditions. This chamber can be cycled.

Chlorides, Temperature, and Water Vapor

A chamber that uses a salty fog at 95°F to maintain one-hundred percent RH values (constant salty moisture) in order to isolate the effects of water vapor, temperature, and chlorides in the absence of UV light. This chamber, often referred to as a salt fog chamber, can be cycled.

UV Light, Temperature, and Water Vapor

The SPHERE chamber uses UV light, in the absence of heat generated from the UV light via use of a heat sink and isolating UV light bulbs, singly or in combination with temperature and water vapor up to eighty-five percent. The UV light can be modified up to the intensity of sixty suns at once. The SPHERE Chamber is a large test apparatus that includes multiple test chambers that can be individually controlled depending which variables are desired. Each chamber can be cycled and the tests parameters can be defined in a multitude of configurations to isolate the variables in a high throughput fashion. This method will be used to isolate the exposure of UV light, temperature, and water vapor in the absence of chlorides. The resulting data will be used to compare to the results from the other chambers with no UV with and without chlorides to determine the driving force of the variables.

Water Vapor and Temperature

A chamber at NIST will also test the same samples that were tested in the

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Center Innovation Fund: KSC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Barbara L Brown

Project Manager:

Luz M Calle

Principal Investigator:

Luz M Calle

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sphere under only the same water vapor and temperature conditions and excluding the UV light in order to determine the effects of moisture and temperature without and in combination with the UV light.

Material to be TestedBare Metal

Uncoated carbon steel 1010, aluminum alloy 2024, and stainless steel 304 metal types are included in this study.

Non-chrome coatings

Aluminum alloy 2024-T3 samples that are coated with hex chrome-free primer systems, leveraged from the GSDO-funded program "Hexavalent Chrome Free Conversion Coating and Primer Analysis, are included in this study.

Corrosion Preventive Coatings or CPCs

Carbon steel, aluminum alloy, and stainless steel metal types that are coated with several different corrosion preventive compounds, leveraged from the GSDO-funded program "Environmentally Friendly Corrosion Preventive Coatings, are included in this study.

Evaluation MethodsFourier Transform Infrared Spectroscopy (FT IR).

FT IR will be used to monitor coating degradation as a function of exposure time for the CPC coatings exposed to each test type.

X-ray Photoelectron Spectroscopy (XPS).

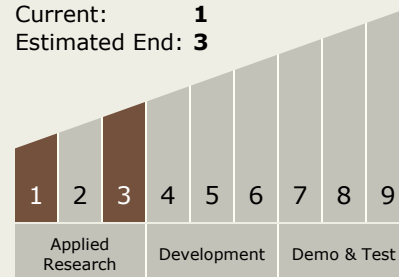
XPS will be used to monitor the sample surface degradation and corresponding deposits as a function of exposure time for all of the sample types. The oxide states will be monitored for changes via high resolution, as well as the general sample composition using the elemental spectrum.

Scanning Electron Microscopy/Energy Dispersive Spectrometry (SEM/EDS).

SEM and EDS will be used to monitor the surface topography and corresponding elemental composition (via elemental mapping) of the sample

Technology Maturity (TRL)

Start: **1**
Current: **1**
Estimated End: **3**

**Technology Areas****Primary:**

- TX13 Ground, Test, and Surface Systems
 - └ TX13.2 Test and Qualification
 - └ TX13.2.1 Mechanical/Structural Integrity Testing



surfaces as a function of exposure time for each test type.

Electrochemical Methods

Steady state electrochemical methods will be used to monitor the degradation of coatings as a function of exposure time for each test type.

Once the testing is performed with the different testing types on all of the samples as a function of exposure time and test type, the variables that most effectively drive the corrosion reactions will be determined. This analysis will aid in the design of an accelerated test method that most accurately predicts long-term atmospheric exposure at KSC. The ideal test method would be able to mimic the initial corrosion reactions that occur naturally in atmospheric exposure.

Anticipated Benefits

This new accelerated test method will:

- reduce NASA's current corrosion prevention coatings qualification timeline from 5 years to less than half a year (estimated).
- improve the development of new materials by providing corrosion/degradation performance data during the technology development process.
- allow new materials to be tested and expedited into end use for NASA applications at a much higher and more reliable rate.

Lifetime prediction of materials is a crucial step in materials selection for critical launch support structures. No accelerated corrosion test methods currently provide accurate life cycle data.

This new accelerated test method will:

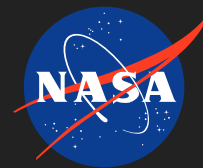
- improve the development of new materials by providing corrosion/degradation performance data during the technology development process.
- allow new materials to be tested and expedited into end use for commercial space industry applications at a much higher and more reliable rate.

Although the new accelerated test method will mimic atmospheric conditions at NASA/KSC, the test could be adapted to simulate terrestrial and extraterrestrial environments.

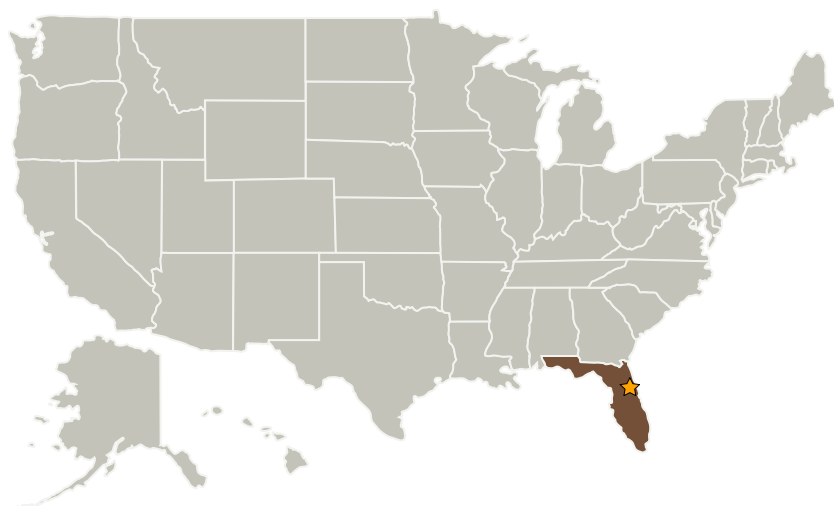
The DoD alone spends \$20 billion annually on corrosion. The development of accelerated methods for lifetime prediction is listed among their top technology needs within the DoD Corrosion Office.

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Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
National Institute of Standards and Technology(NIST)	Supporting Organization	US Government	Boulder, Colorado

Co-Funding Partners	Type	Location
National Institute of Standards and Technology(NIST)	US Government	Boulder, Colorado

Primary U.S. Work Locations
Florida

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Images



Long-term atmospheric exposure testing

Beachside Atmospheric Exposure Test Site at NASA's Kennedy Space Center

(<https://techport.nasa.gov/image/4047>)

Links

KSC-13922

(no url provided)